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SUMMARY

Aerodynamic characteristics of a tapered NACA 23012 airfoil with single and double perforated split flaps have been determined in the NACA 7- by 10-foot wind tunnel. Dynamic pressure surveys were made behind the airfoil at the approximate location of the tail in order to determine the extent and location of the wake for several of the flap arrangements. In addition, computations have been made of an application of perforated double split flaps for use as fighter brakes.

The results indicated that single or double perforated split flaps may be used to obtain satisfactory dive control without undue buffeting effects and that single or double perforated split flaps may also be used as fighter brakes.

The perforated split flaps had approximately the same effects on the aerodynamic and wake characteristics of the tapered airfoil as on a comparable rectangular airfoil.

INTRODUCTION

The NACA has undertaken an extensive investigation for the purpose of developing devices suitable for limiting the diving speeds of airplanes. As a part of this investigation a study has been made of test results obtained during the development of devices designed primarily for other purposes, such as high lift or lateral control, but which may also be used for dive control. The slot-lip aileron combined with a full-span slotted flap is one of those dual-purpose devices, and data for its use have been presented in reference 1. A study was also made of a large amount of uncorrelated data on various airfoil-flap combinations from tests previously made for the Bureau of Aeronautics. This study indicated that perforated double split flaps would give the desired characteristics for use as dive-control devices. Following this study, an investigation was made of several arrangements of single and double split flaps on a rectangular NACA 23012 airfoil (reference 2) to determine in more detail the aerodynamic and wake characteristics of those devices in order that designers might more closely evaluate their effects on the performance of complete airplanes. The present tests were made to determine the aerodynamic and wake characteristics of some of the single and double split-flap arrangements on a tapered NACA 23012 airfoil.

APPARATUS AND TESTS

Model

The airfoil model used (fig. 1) was of laminated mahogany built to the NACA 23012 profile. The model was tapered 3 to 1 in plan form with a span of 60 inches and an aspect ratio of 6.0. The trailing edge of the model was straight and the maximum upper-surface ordinates of the various sections were in one plane. The perforated split flaps were made of sheet steel and had a chord of 2 inches (20 percent of the airfoil mean geometric chord). The perforations in the flaps were symmetrically spaced circular holes (see flap detail, fig. 1) and removed 33.1 percent of the original flap area. In order to facilitate partial-span-flap tests each flap was made in ten equal segments, each segment having a span of 20 percent of the airfoil semispan. The segments on each semispan were numbered from 1 to 5 progressively from the plane of symmetry outboard to the airfoil tip. Split-flap deflections were measured with respect to the airfoil surface at the hinge point and the gap between the airfoil surface and the flap was sealed with modeling clay.

Wind Tunnel and Equipment

The tests were made in the NACA 7- by 10-foot closed-throat wind tunnel described in references 3 and 4. The wake surveys were made with a rake of eight 3/8-inch diameter pitot tubes spaced 2 inches apart. The rake was adjustable so that dynamic pressure could be recorded at 1-inch intervals along a vertical line 27 inches long which was located 30 inches (3.0c) behind the quarter-chord point of the airfoil mean aerodynamic chord and 5 inches (0.5c) to the right of the plane of symmetry. This position was believed to be representative of the location of the hinge line and midpoint of the semispan of the horizontal tail surfaces of airplanes on which dive-control devices would be used. The ratio of the dynamic pressures in the wake to the dynamic pressures at the same points with the model removed (support strut in place) was determined from readings on an inclined-tube alcohol manometer. Figure 2 is a three-quarter rear view of the model mounted in the wind tunnel.

Tests

Test conditions.- The dynamic pressure maintained for all tests was 16.37 pounds per square foot, which corresponds to a velocity of about 80 miles per hour under standard sea-level conditions and to an average test Reynolds number of 609,000 based on the mean geometric chord of the model (10 in.).

Test procedure.- The tests consisted of the determination of the lift, drag, and pitching-moment coefficients and of the wake characteristics for various arrangements of the flaps. Double split flaps were located 20 percent of the mean geometric chord from the airfoil trailing edge and single split flaps (lower surface) were located on the line of the 30-percent-chord stations of the airfoil sections. The forces and moments were determined at intervals of 2° throughout the angle-of-attack range from below zero lift to above maximum lift. The wake surveys were made at intervals of 4° throughout the same angle-of-attack range.

No tests were made with the flap perforations covered since the data in reference 2 showed that while covering the perforations increased the drag coefficient, it also caused a very unsteady condition of the model.

RESULTS AND DISCUSSION

In the presentation of results the following symbols are used:

C_L lift coefficient, L/q_oS

C_D drag coefficient, D/q_oS

$C_{m_{\bar{c}/4}}$ pitching-moment coefficient about the quarter-chord point of the airfoil mean aerodynamic chord, $m/q_o\bar{c}S$

q/q_o dynamic pressure ratio

where

L lift

D drag

m pitching moment

q dynamic pressure at point in wake, $\frac{1}{2}\rho V^2$

q_o average dynamic pressure for air stream, $\frac{1}{2}\rho V_o^2$

c airfoil mean geometric chord

$\bar{c}$ airfoil mean aerodynamic chord, chord through centroid of area of airfoil semispan

c_f flap chord

S airfoil area

b airfoil span

b_f flap span

and

α angle of attack

δ_{f_U} upper-surface split-flap deflection

δ_{f_L} lower-surface split-flap deflection

The subscript L_o refers to the characteristics at zero lift.

Since the support strut interference and tares were relatively small, these corrections were applied only to

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the plain airfoil data. The standard jet-boundary corrections which were applied to all the force-test data are:

$$\Delta\alpha_i^o = \delta \frac{S}{C} C_L \, 57.3$$

$$\Delta C_{D_i} = \delta \frac{S}{C} C_L{}^2$$

where C is the jet cross-sectional area. A value of $\delta = 0.1125$ for the closed-throat wind tunnel was used in correcting the results. It should be noted that due to the various span-load distributions of the airfoil with the various split-flap arrangements, these corrections are not strictly applicable to all the data. No correction for tunnel effect has been applied to the wake location. This correction is small because of the relatively small model used.

Double Split Flaps

The aerodynamic and wake characteristics of a 60-inch span 3-to-1 tapered NACA 23012 airfoil with double split flaps located 0.20c from the airfoil trailing edge are presented in figures 3, 4, and 5. The aerodynamic characteristics are presented as curves plotted against lift coefficient; and the wake characteristics are shown as curves of dynamic pressure ratio, q/q_o, plotted against distance above and below the extended chord line of the root section of the airfoil. The method of presenting the wake characteristics is illustrated in figure 4. The double split flaps had practically the same effects on the aerodynamic and wake characteristics of the tapered airfoil as they had on those of the rectangular airfoil of reference 2. The wake surveys were made of selected representative arrangements based on the results of reference 2 and the data presented are sufficient to show the wake characteristics of all arrangements.

Since the aerodynamic characteristics at and near zero lift were considered of particular interest to the designer, the results from figures 3a and 5a were plotted against flap span in figure 6. Neither flap span nor airfoil plan form had a marked effect on the pitching-moment coefficients or angles of attack at zero lift. The drag coefficients obtained with center-section double split flaps were practically the same for both the tapered airfoil and the rectangular airfoil of reference 2, but the tip-section flaps gave higher drag coefficients on the tapered airfoil than on the rectangular airfoil. On both airfoils the center-section flaps allowed higher available maximum lift coefficients than the tip-section flaps except for one unexplained instance (60-percent-span flaps, fig. 6). The difference between the maximum lift coefficients obtainable with the center- and tip-section flaps was less for the tapered airfoil than for the rectangular airfoil of reference 2.

Single Split Flaps

The aerodynamic and wake characteristics of a 3-to-1 tapered NACA 23012 airfoil with lower-surface perforated split flaps located on a line through the 30-percent-chord stations of the airfoil sections are shown in figures 7 to 9. The use of these flaps produced the same large decrease in angle of attack for zero lift on the tapered airfoil as on the rectangular airfoil of reference 2. Since the aerodynamic characteristics at and near zero lift were considered of particular interest to the designer, the results of figures 8 and 9 were replotted against flap span in figure 10.

In view of the agreement shown between the tapered airfoil tests and the rectangular airfoil tests of reference 2, the two sets of data together should afford sufficient information for the prediction of the performance of perforated split flaps when used as dive brakes.

Diving Speed

The relationship between drag coefficient, wing loading, and indicated velocity for an airplane in a vertical dive is shown in figure 11. For other diving angles, the velocity given on the chart should be multiplied by the square root of the sine of the diving angle, referred to the horizontal. From this chart, the data in figures 3(a) through 10, and the data in figures 3(a) through 21(a) of reference 2, it may be shown that the use of full-span perforated double split flaps would probably limit to 200 miles per hour the indicated diving speed of an airplane with a wing loading of 35 pounds per square foot and limit to 250 miles per hour the diving speed of an airplane with a wing loading of 55 pounds per square foot. Corresponding values obtained with the use of perforated single split flaps are: 200 miles per hour for a wing loading of 30 pounds per square foot, and 250 miles per hour for a wing loading of 45 pounds per square foot.

Fighter Brakes

In addition to the need for devices which will reduce the diving speeds of airplanes, it appears that a need has arisen for some device which will temporarily reduce the speed of attacking fighter aircraft in order that the pilot will have more time for firing. Some of the requirements which a fighter brake should meet are: little or no change in the attitude of the airplane with fixed controls, sufficient increase in lift coefficient during operation of the brakes to maintain level flight as the speed is reduced, and enough increase in drag coefficient to decelerate the airplane within a reasonable time after the brakes are applied.

An application of fighter brakes to an airplane with a wing loading of 30 pounds per square foot has been computed by an approximate, step-by-step method. The arrangement used was the full-span perforated double split flaps located at 0.80c on the rectangular NACA 23012 airfoil (fig. 3(a), reference 2). It was assumed that both the upper-surface and the lower-surface flaps were deflected to 30° within 1 second, and then the upper-surface flap remained stationary while the lower-surface flap was deflected to 60° in such a manner as to afford sufficient increase in lift coefficient to maintain level flight at the reduced speeds without a change in angle of attack. Although maintaining a constant power output of the engine would slightly decrease the effective drag increment and increase the time required to slow down, this effect was neglected in order to simplify the problem.

The results of the computations are given in figure 12, which shows curves of speed; lift, drag, and pitching-moment coefficients; angle of attack; flap deflection; and acceleration plotted against time. As is shown in figure 11, the use of full-span perforated double split flaps should reduce the airplane speed from 300 miles per hour to 176 miles per hour in about 8 seconds, with a negligible change in angle of attack and a change in wing pitching-moment coefficient of only -0.03. It should be noted that at the end of the 8 seconds the airplane still has a deceleration of about 0.6g and in order to continue in level flight the lift coefficient must be increased by an increase in angle of attack or by a decrease in the upper-surface flap deflection (which would also decrease the drag coefficient and deceleration).

The effect of the flaps on the pitching-moment coefficient due to the tail should be determined on a complete model of any proposed installation. Also a more complete determination should be made of the variation of lift and drag coefficients with flap deflection, since the lift and drag data used in computing the characteristics shown in figure 12 were taken from curves drawn between $\delta_f = 30^\circ$ and $\delta_f = 60^\circ$ with no intermediate points.

In using double split flaps as fighter brakes, the initial acceleration of 1.1g could be reduced by decreasing the initial 30° flap deflection or by reducing the rate of deflection and using a differential between the two flaps, so that the greater deflection of the lower-surface flap would supply the lift coefficients needed to maintain a constant angle of attack.

It also appears possible to use lower-surface perforated split flaps located near the wing leading edge as fighter brakes if a somewhat lower deceleration and some change in the attitude of the airplane is considered acceptable.

Operating Forces

A large amount of data has been published on the hinge-moment characteristics of various split-flap combinations, some of which are presented in references 5 to 8; and the hinge-moment characteristics of a slot-lip aileron for use as a dive brake when combined with a full-span slotted flap are presented in reference 1. Comparatively little is known, however, about the effects of flap perforations or of various methods of operation on the forces required to deflect split flaps. Some work has been done in England on various methods of operation of split flaps (reference 9) and brief mention is made of the loads to be expected on dive brakes in a report of some German research (reference 10). The dive brakes of reference 10 were slats placed normal to the airfoil surface with a gap between the airfoil and the slats. Pressure distribution tests on these slats indicated that the load on the slats was about 75 percent of the drag increase and that the distribution of this load on the slat was approximately rectangular.

Additional research is recommended on the effects of perforations and method of flap operation on the hinge-moment characteristics of perforated split flaps.

CONCLUSIONS

The results indicated that single or double perforated split flaps may be used to obtain satisfactory dive control without undue buffeting effects and that single or double perforated split flaps may also be used as fighter brakes.

The perforated split flaps have approximately the same effects on the aerodynamic and wake characteristics of the tapered airfoil as on a comparable rectangular airfoil.

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REFERENCES

1. Rogallo, F. M.: Aerodynamic Characteristics of a Slot-Lip Aileron and Slotted Flap for Dive Brakes. NACA ACR, April 1941.

2. Purser, Paul E., and Turner, Thomas R.: Wind-Tunnel Investigation of Perforated Split Flaps for Use as Dive Brakes on a Rectangular NACA 23012 Airfoil. NACA ACR, July 1941.

3. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the National Advisory Committee for Aeronautics. NACA Rep. No. 412, 1931.

4. Wenzinger, Carl J., and Harris, Thomas A.: Wind-Tunnel Investigation of an NACA 23012 Airfoil with Various Arrangements of Slotted Flaps. NACA Rep. No. 664, 1939.

5. Weick, Fred E., and Wenzinger, Carl J.: Wind-Tunnel Research Comparing Lateral Control Devices, Particularly at High Angles of Attack. XII - Upper-Surface Ailerons on Wings with Split Flaps. NACA Rep. No. 499, 1934.

6. Wenzinger, Carl J.: Wink-Tunnel Measurements of Air Loads on Split Flaps. NACA TN No. 498, 1934.

7. Wenzinger, Carl J.: Pressure Distribution over a Clark Y-H Airfoil Section with a Split Flap. NACA TN No. 627, 1937.

8. Wenzinger, Carl J., and Rogallo, Francis M.: Résumé of Air-Load Data on Slats and Flaps. NACA TN No. 690, 1939.

9. Irving, H. B., and McMillan, G. A.: Some Experiments on the Balancing of Wing Brake Flaps. R. & M. No. 1864, British A.R.C., 1939.

10. Jacobs, Hans, and Wanner, Adolf: DFS Dive-Control Brakes for Gliders and Airplanes; and Wanner, Adolf: Analytical Study of the Drag of the DFS Dive-Control Brake. NACA TM No. 926, 1940.

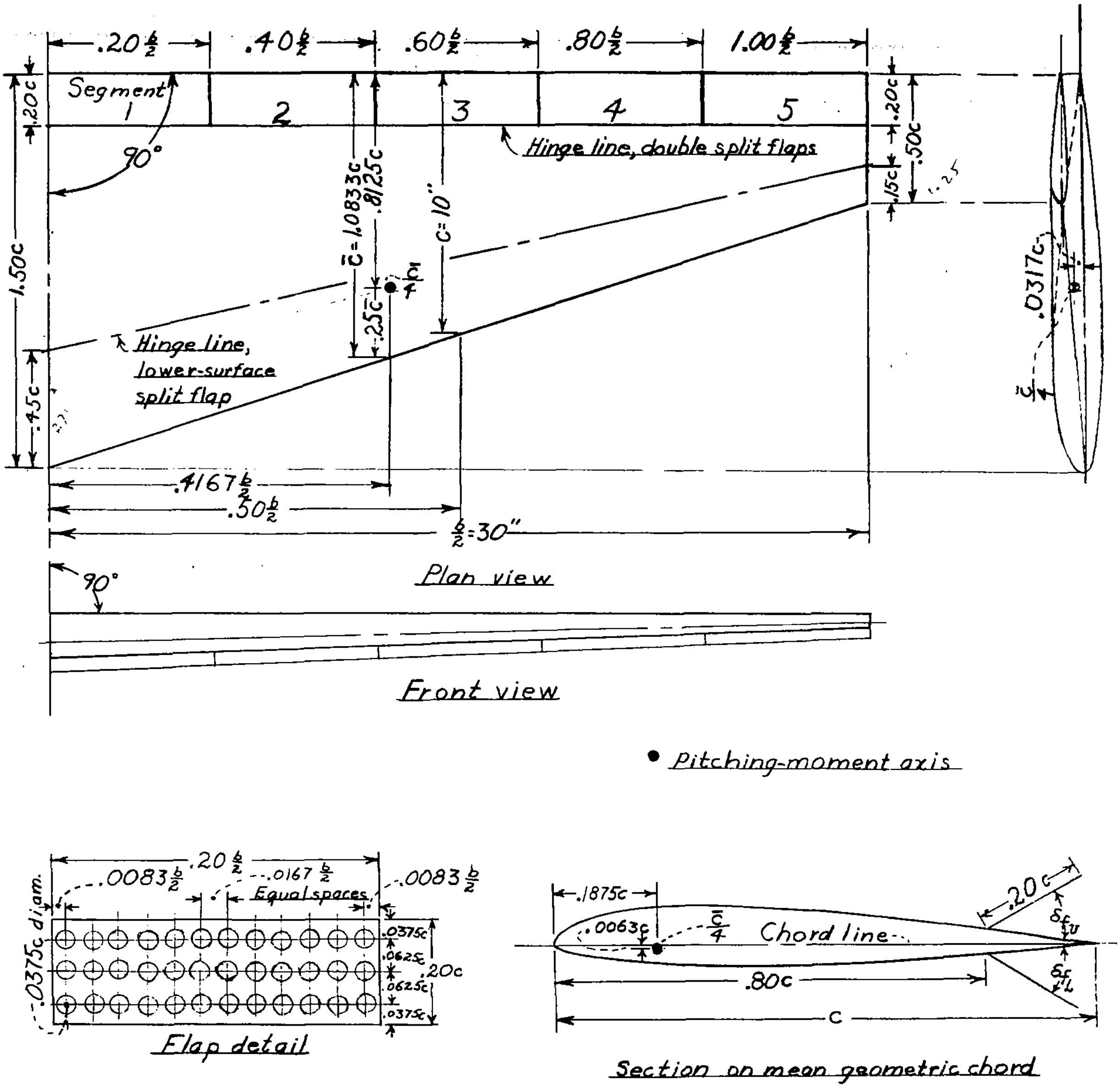


FIGURE 1.- The 3:1 tapered NACA 23012 airfoil with 0.20c perforated split flaps. Perforations remove 33.1 percent of the original flap area. Airfoil span, 60 inches; mean geometric chord, 10 in.; mean aerodynamic chord, 10.833 inches.

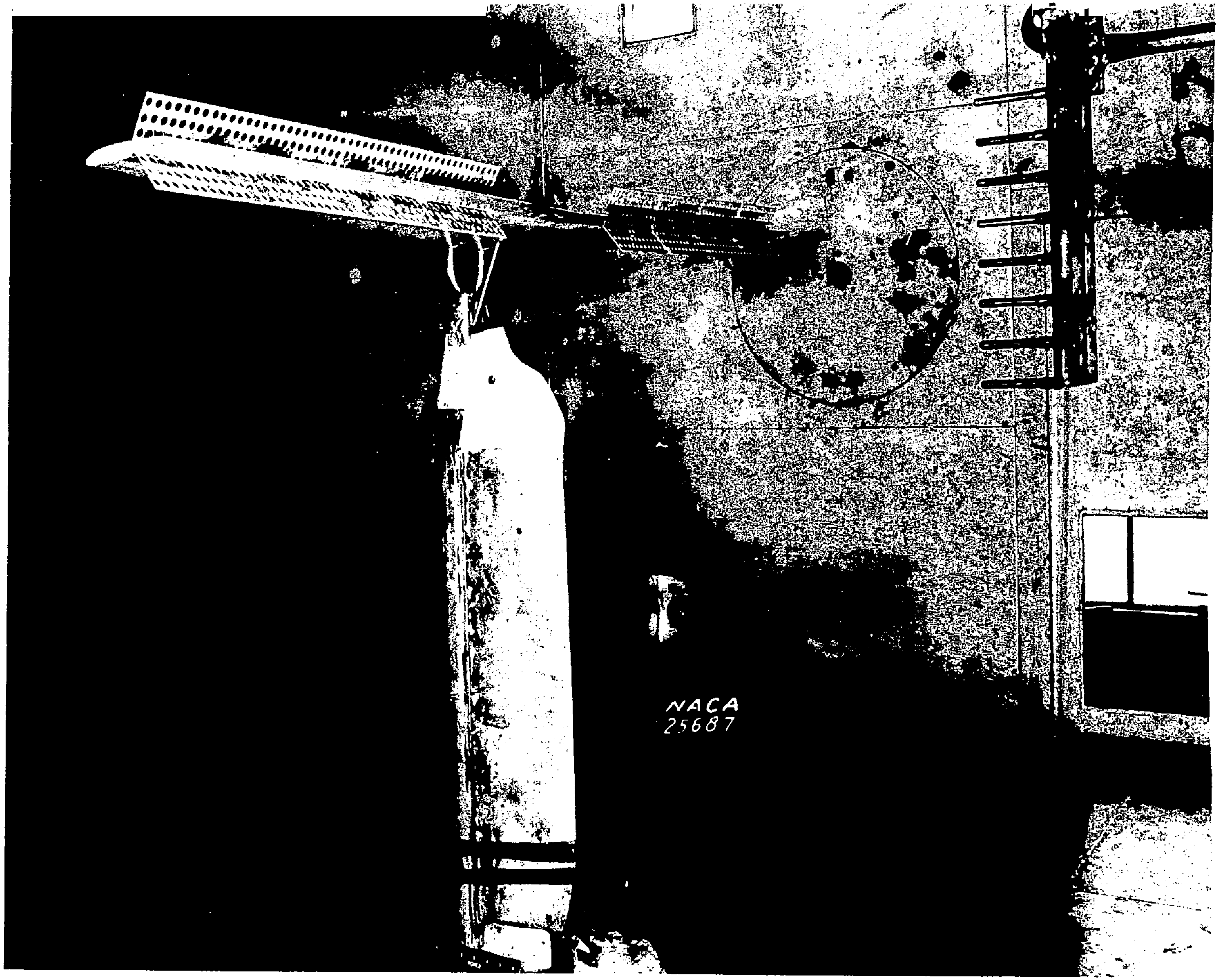
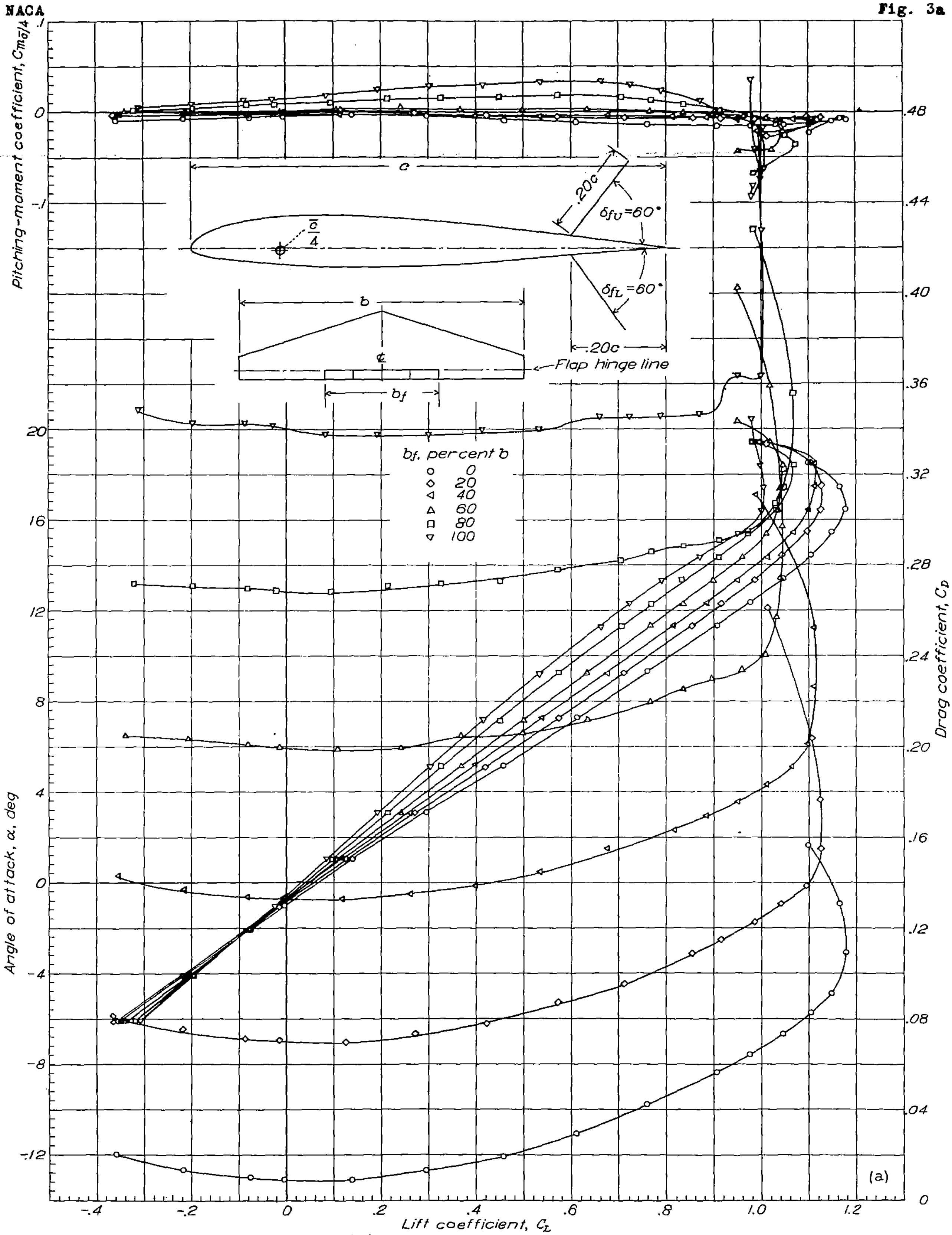
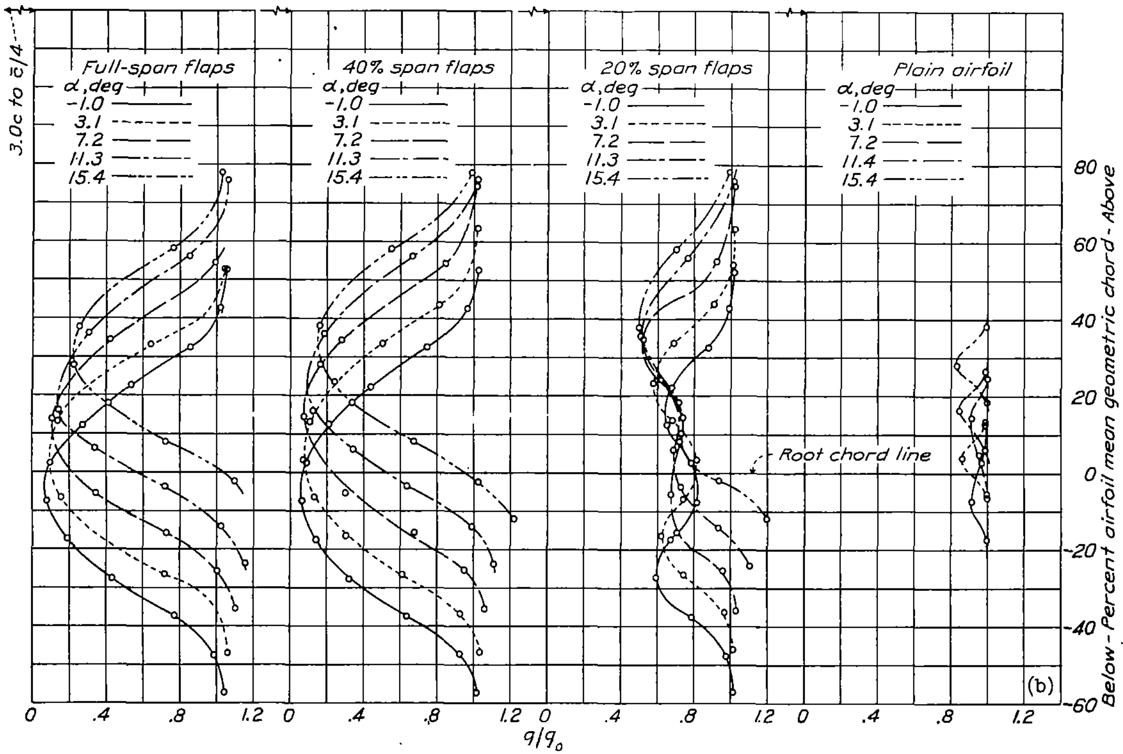


Figure 2.- Three-quarter rear view of the 3:1 tapered NACA 23012 airfoil with 0.20c, 80-percent-span tip section perforated double split flaps mounted in the NACA 7-by 10-foot wind tunnel.



(a) Aerodynamic characteristics.

Figure 3 (a).- Effect of 0.20c partial-span center-section perforated double split flaps located 0.20c from the airfoil trailing edge of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_U},60°; δ_{f_L},60°.



(b) Wake characteristics.
Figure 3 (b).- Effect of 0.20c partial-span center-section perforated double split flaps located 0.20c from the airfoil trailing edge of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_U},60°; δ_{f_L},60°.

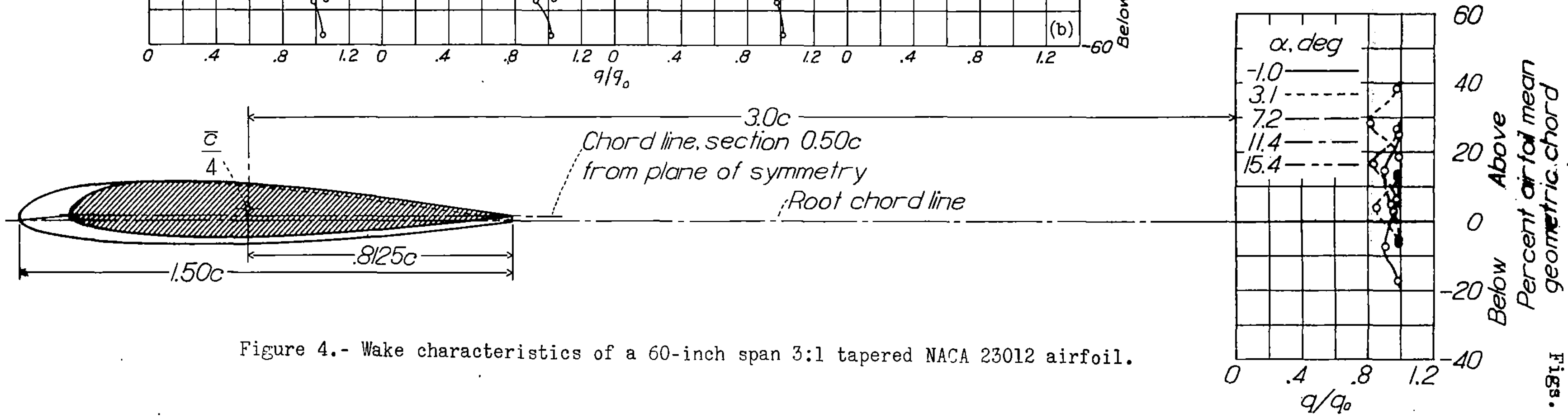
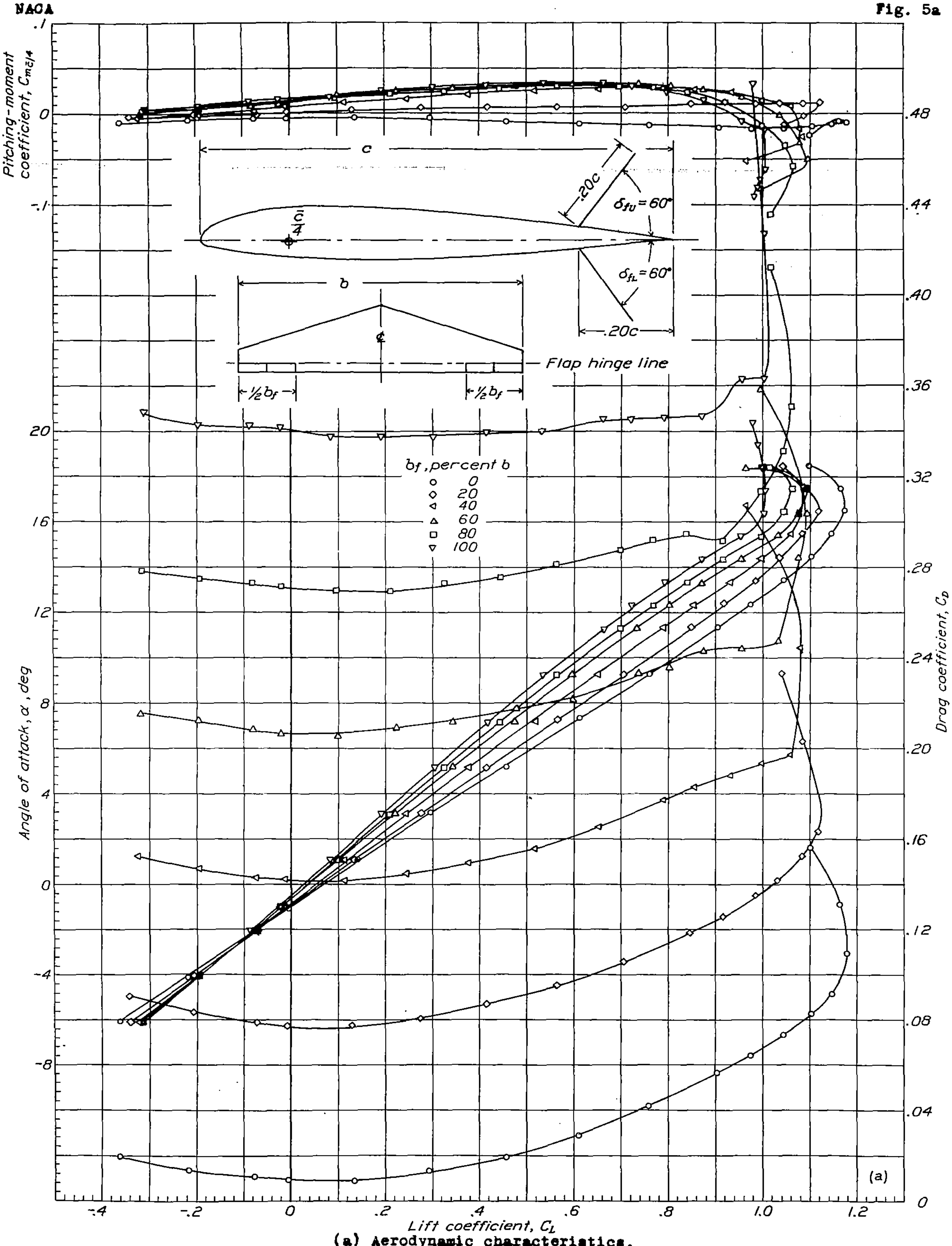


Figure 4.- Wake characteristics of a 60-inch span 3:1 tapered NACA 23012 airfoil.



(a) Aerodynamic characteristics.

Figure 5 (a).- Effect of 0.20c partial-span tip-section perforated double split flaps located 0.20c from the airfoil trailing edge of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_U},60°; δ_{f_L},60°.

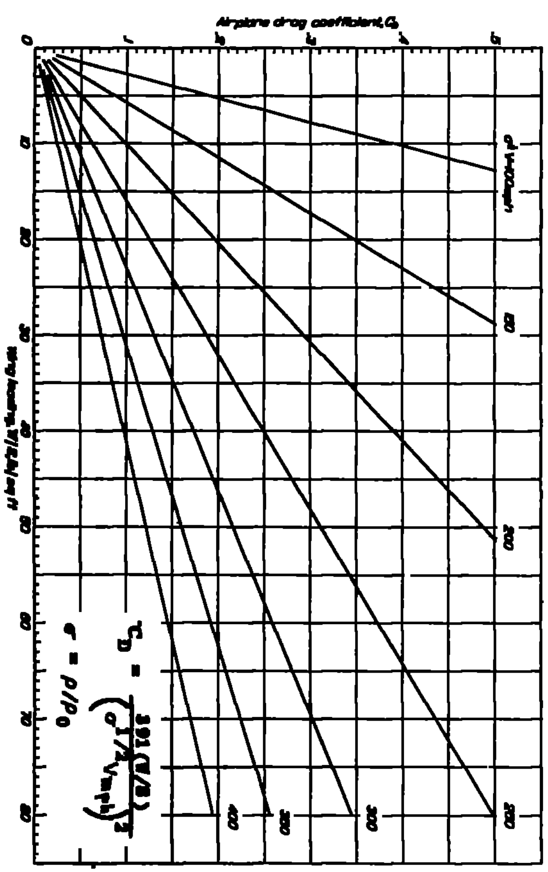
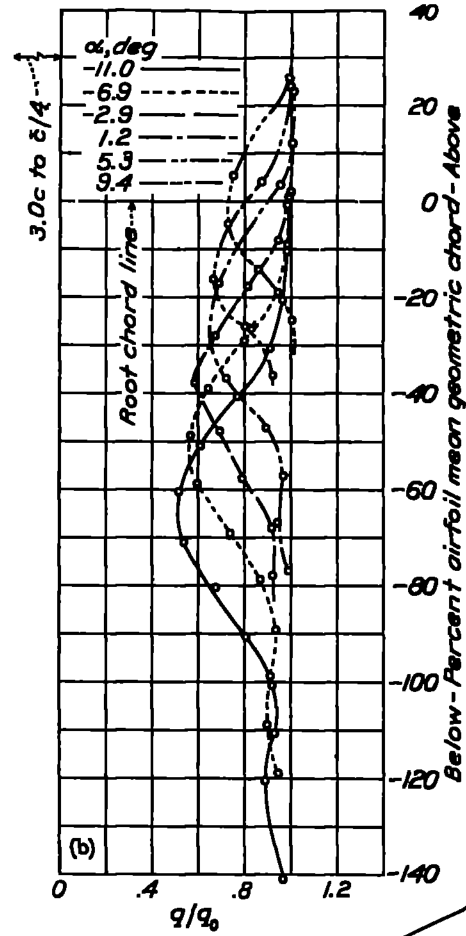
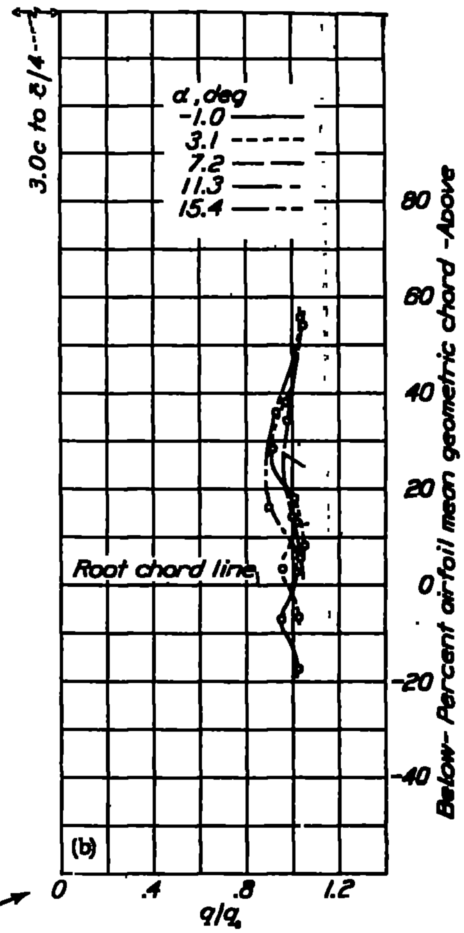


Figure 11.- Indicated terminal diving speeds of airplanes with various wing loadings and drag coefficients.



(b) Wake characteristics.

Figure 7 (b).- Effect of a 0.20c full-span lower-surface perforated single split flap located on a line through the 30-percent-chord stations of the airfoil sections of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_L},60°.



(b) Wake characteristics.

Figure 5 (b).- Effect of 0.20c 80-percent-span tip-section perforated double split flaps located 0.20c from the airfoil trailing edge of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_U},60°; δ_{f_L},60°.

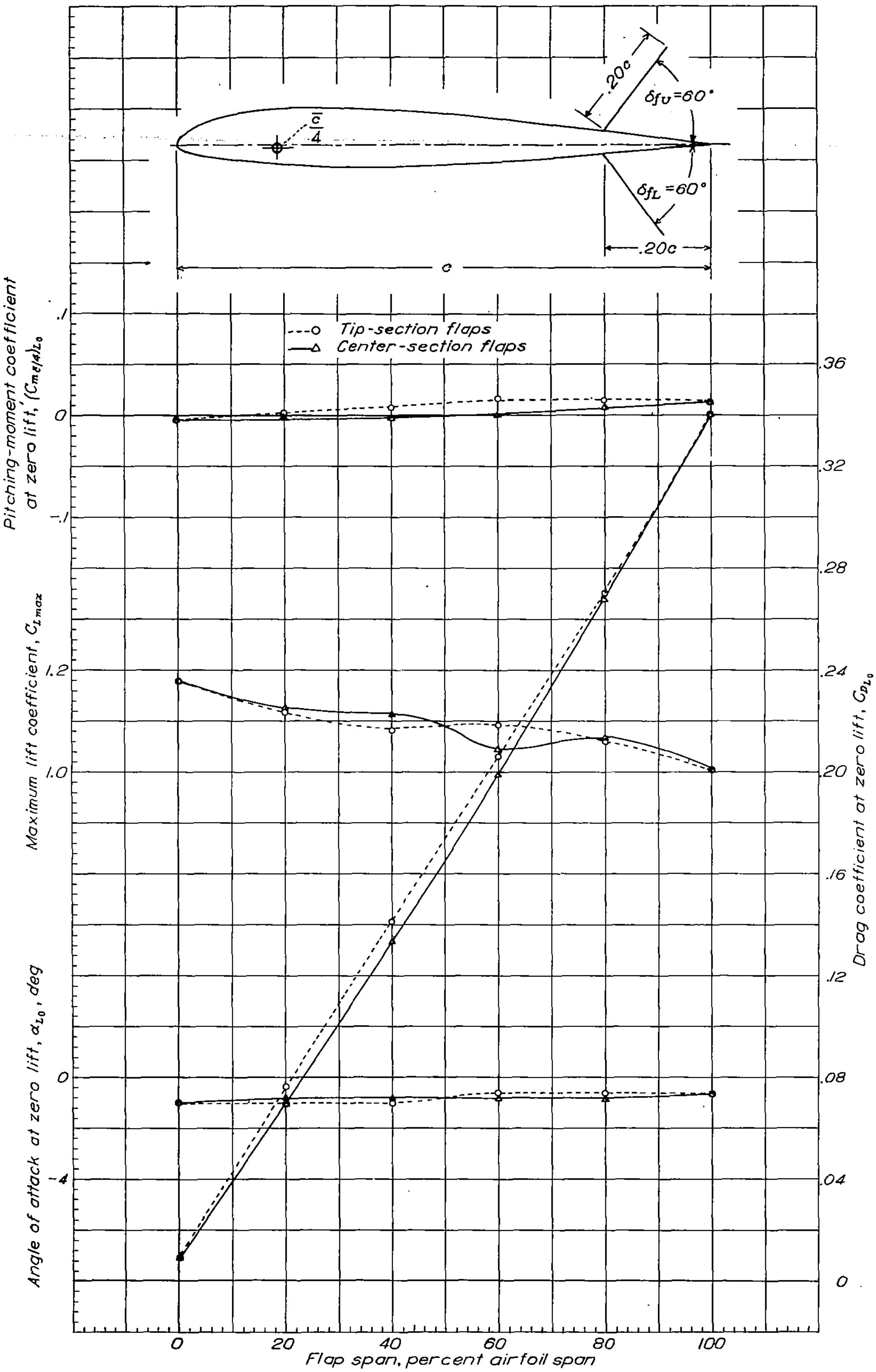
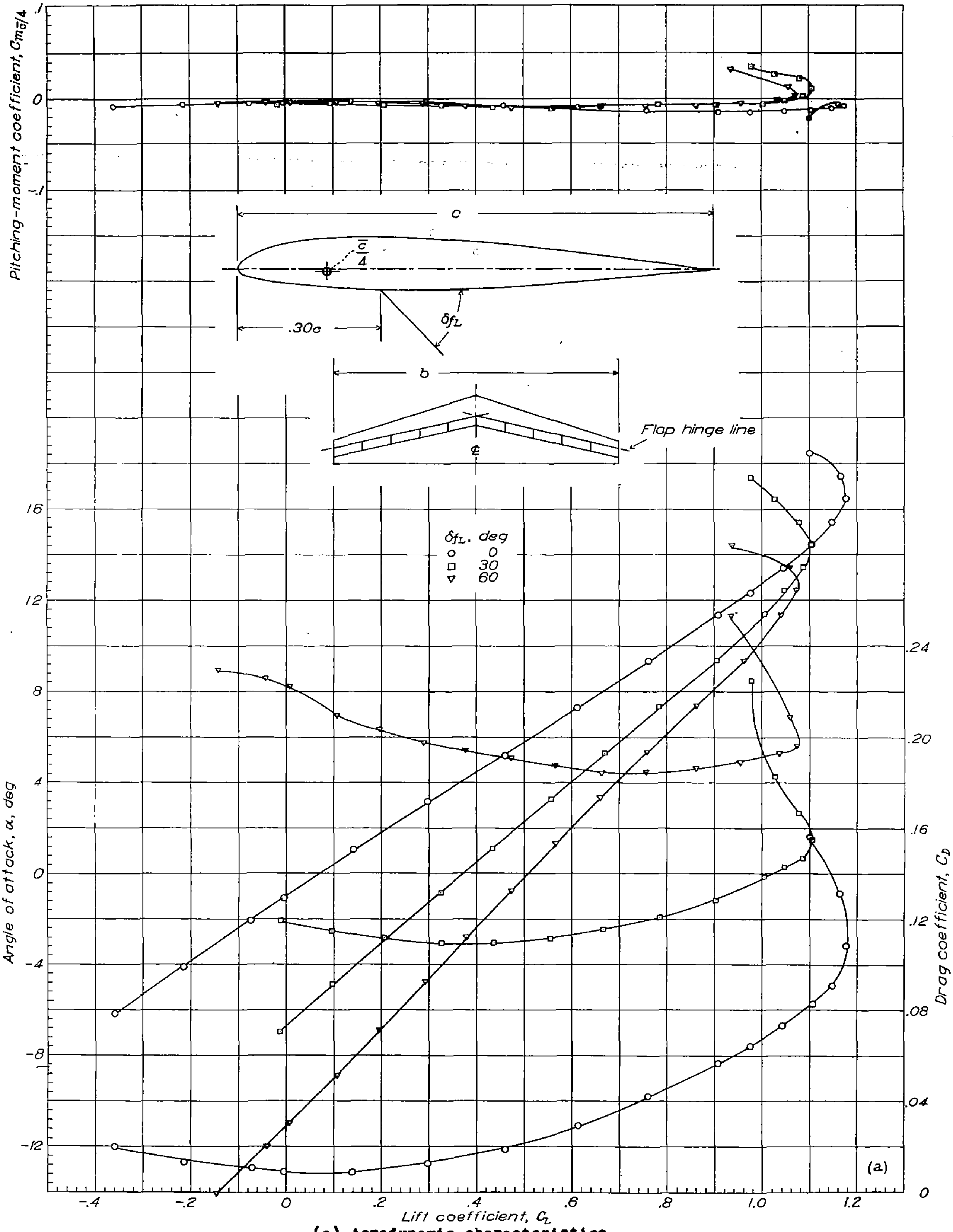


Figure 6.- Effect of flap span on some of the aerodynamic characteristics of a 60-inch span 3:1 tapered NACA 23012 airfoil with 0.20c perforated double split flaps located 0.20c from the airfoil trailing edge. δ_{f_U},60°; δ_{f_L},60°.



(a) Aerodynamic characteristics.

Figure 7 (a).- Effect of a 0.20c full-span lower-surface perforated single split flap located on a line through the 30-percent-chord stations of the airfoil sections of a 60-inch span 3:1 tapered NACA 23012 airfoil.

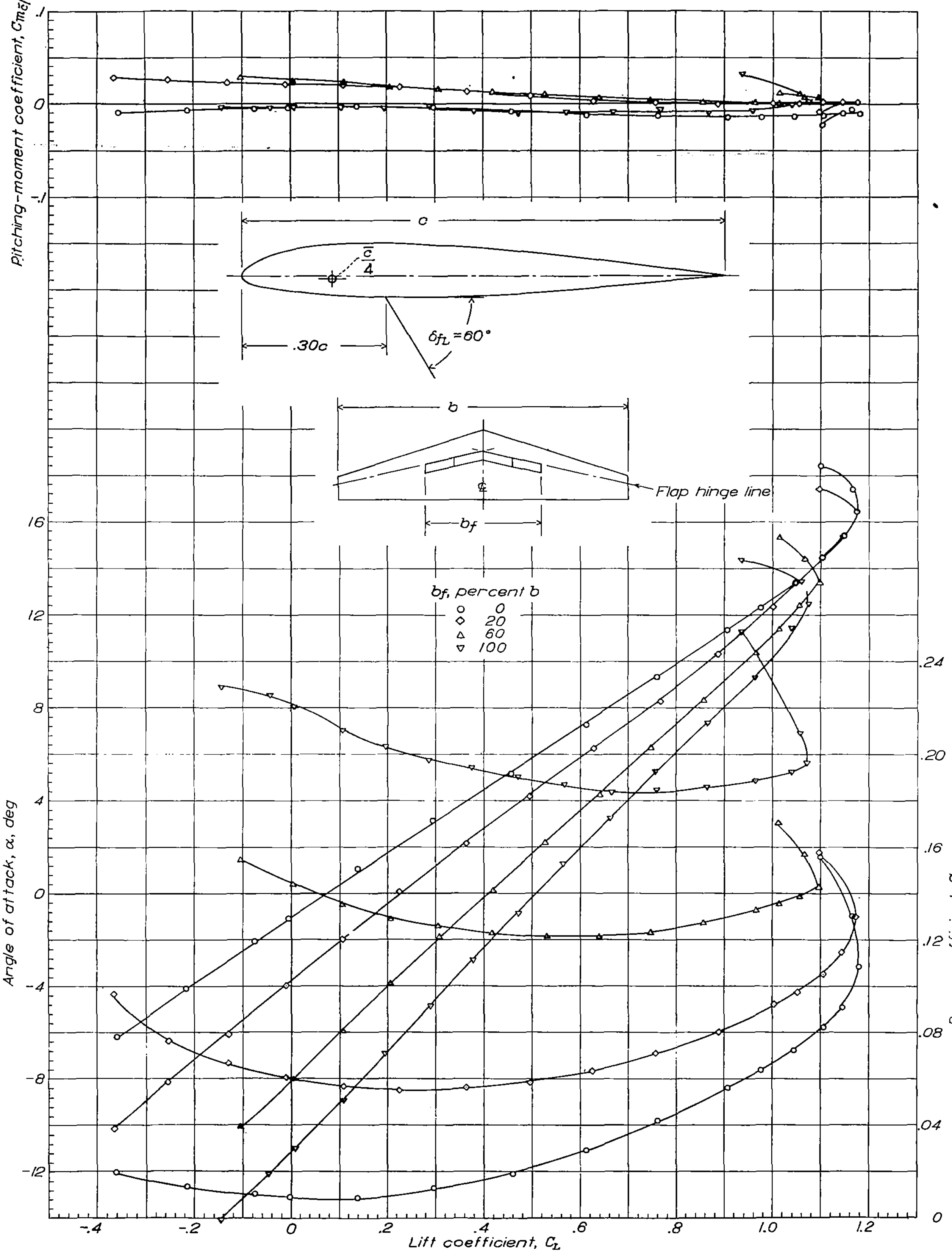


Figure 8.- Effect of 0.20c partial-span lower-surface center-section perforated single split flaps located on a line through the 30-percent-chord stations of the airfoil sections on the aerodynamic characteristics of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_L},60°.

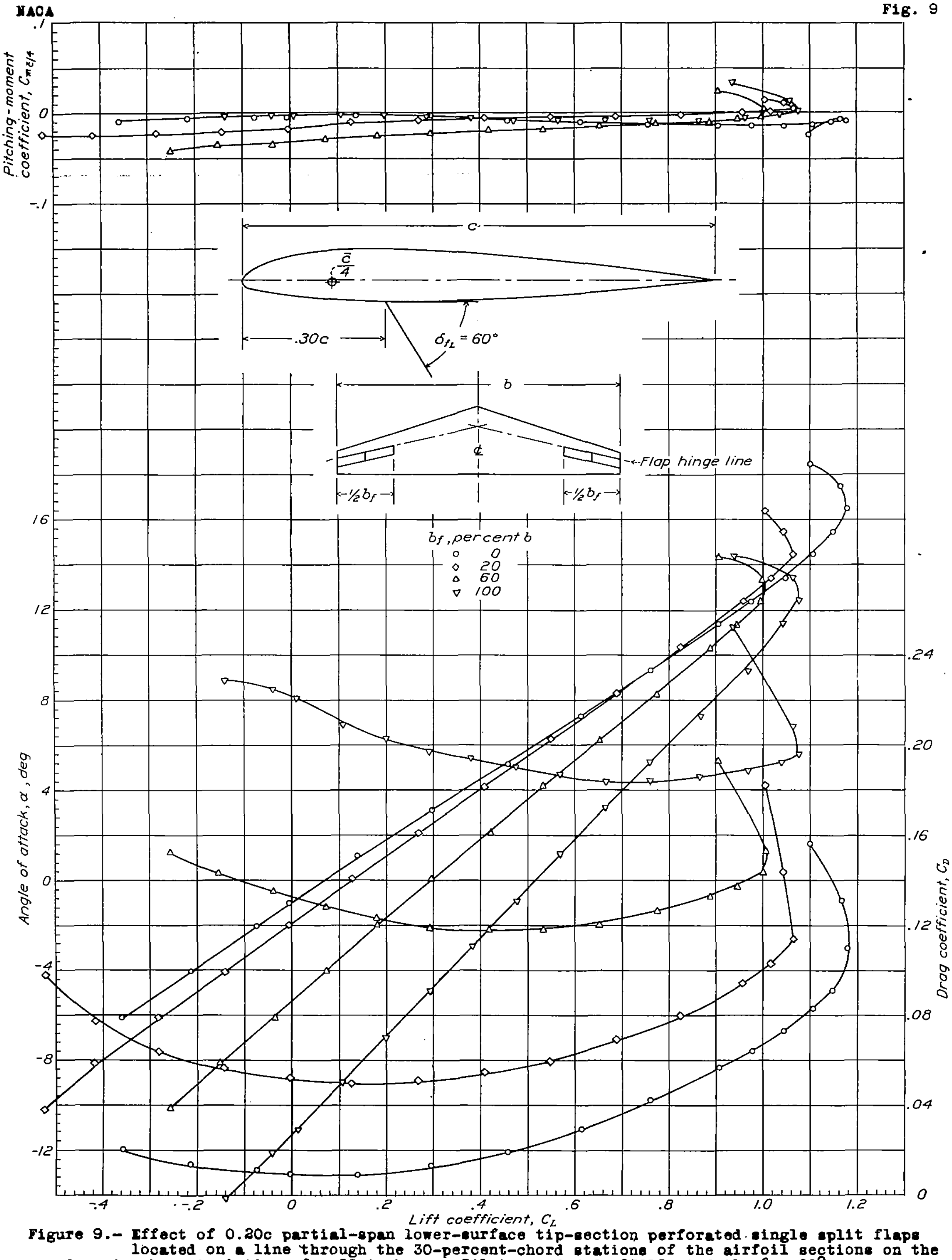


Figure 9.- Effect of 0.20c partial-span lower-surface tip-section perforated single split flaps located on a line through the 30-percent-chord stations of the airfoil sections on the aerodynamic characteristics of a 60-inch span 3:1 tapered NACA 23012 airfoil. δ_{f_L},60°.

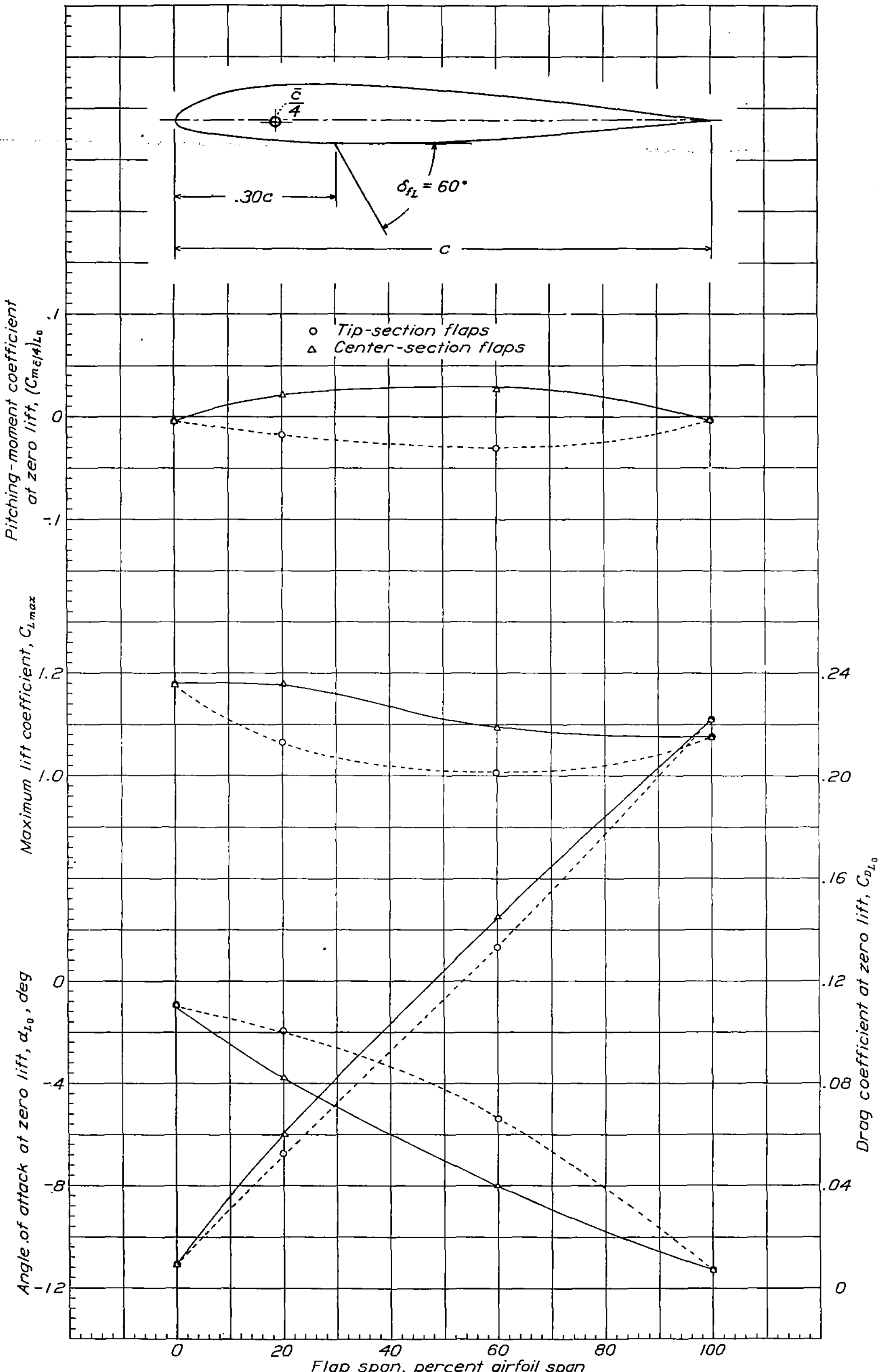


Figure 10.- Effect of flap span on some of the aerodynamic characteristics of a 60-inch span 3:1 tapered NACA 23012 airfoil with 0.20c lower-surface perforated single split flaps located on a line through the 30-percent-chord stations of the airfoil sections. δ_{f_L}, 60°.

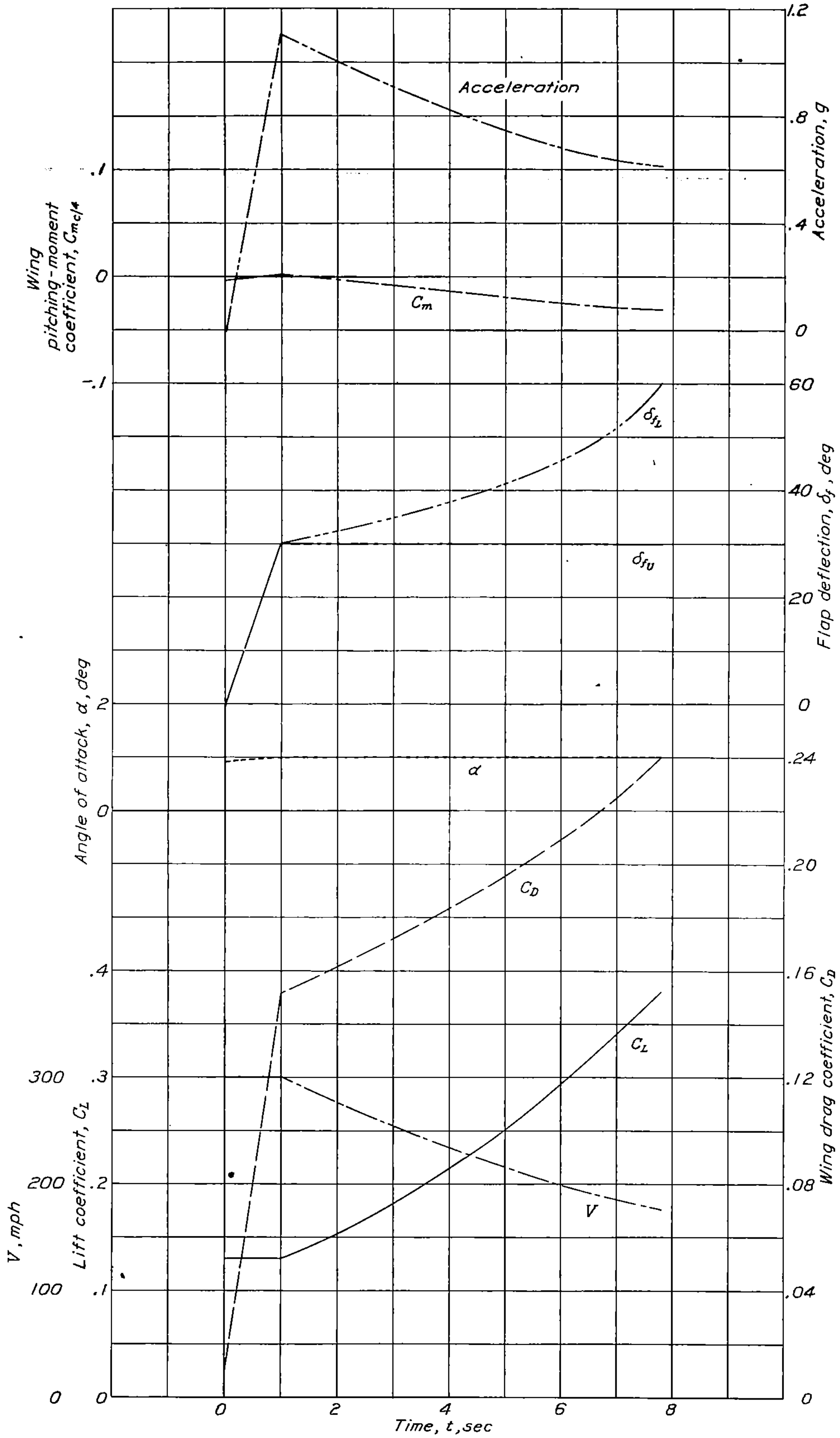


Figure 12.- Computed time-history characteristics during deceleration of an airplane equipped with fighter brakes consisting of 0.20c full-span perforated double split flaps located 0.80c from the wing leading edge.